Exploring Extreme Environments with Space Robots

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Date: 9/28/17

Jet Propulsion Laboratory
California Institute of Technology


ASRL

My Background

A.A.

MESA COMMUNITY COLLEGE

'09

B.Sc. Earth & Space Systems Design

School of Earth and Space Exploration

Arizona State University

'12

STEM Scholar

FULBRIGHT CANADA

'13

PhD Aerospace

UNIVERSITY OF TORONTO

'17

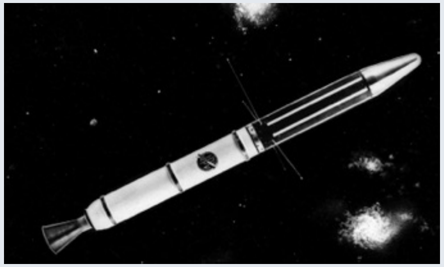
Jet Propulsion Laboratory
California Institute of Technology

Jet Propulsion Laboratory
California Institute of Technology

JPL Overview

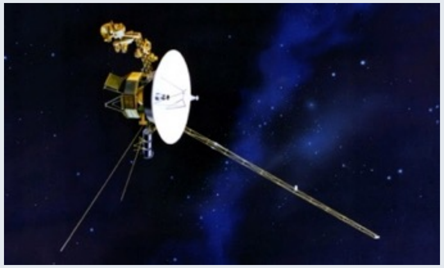
- Located in Pasadena, California
- One of 10 NASA Centers
- Founded in the 1930s

JPL Firsts



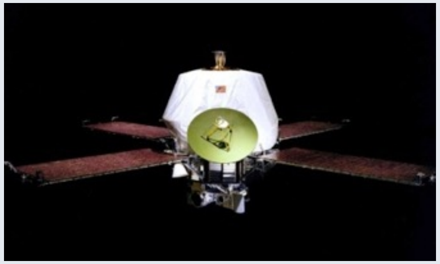
- 1st U.S. satellite
- 1958 – Explorer 1

- 1st Close-up images of another planet
- 1964 – Mariner 4 / Mars



- 1st Fly-bys of Neptune and Uranus
- 1986, 1989 – Voyager 2

- 1s t U.S. Spacecraft to the moon
- 1964 – Ranger 7

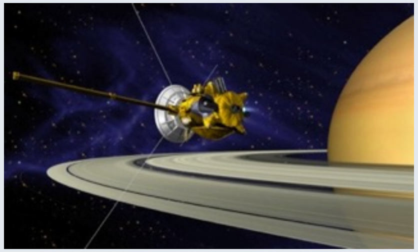


- 1st orbiter at another planet
- 1971 – Mariner 9 / Mars

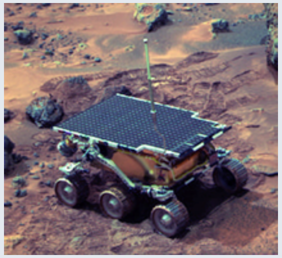
- 1st orbiter at Jupiter
- 1979 – Galileo

- 1st planetary mission
- 1962 - Mariner 2 /Venus

- 1st gravity assist mission
- 1974 – Mariner 10/ Venus

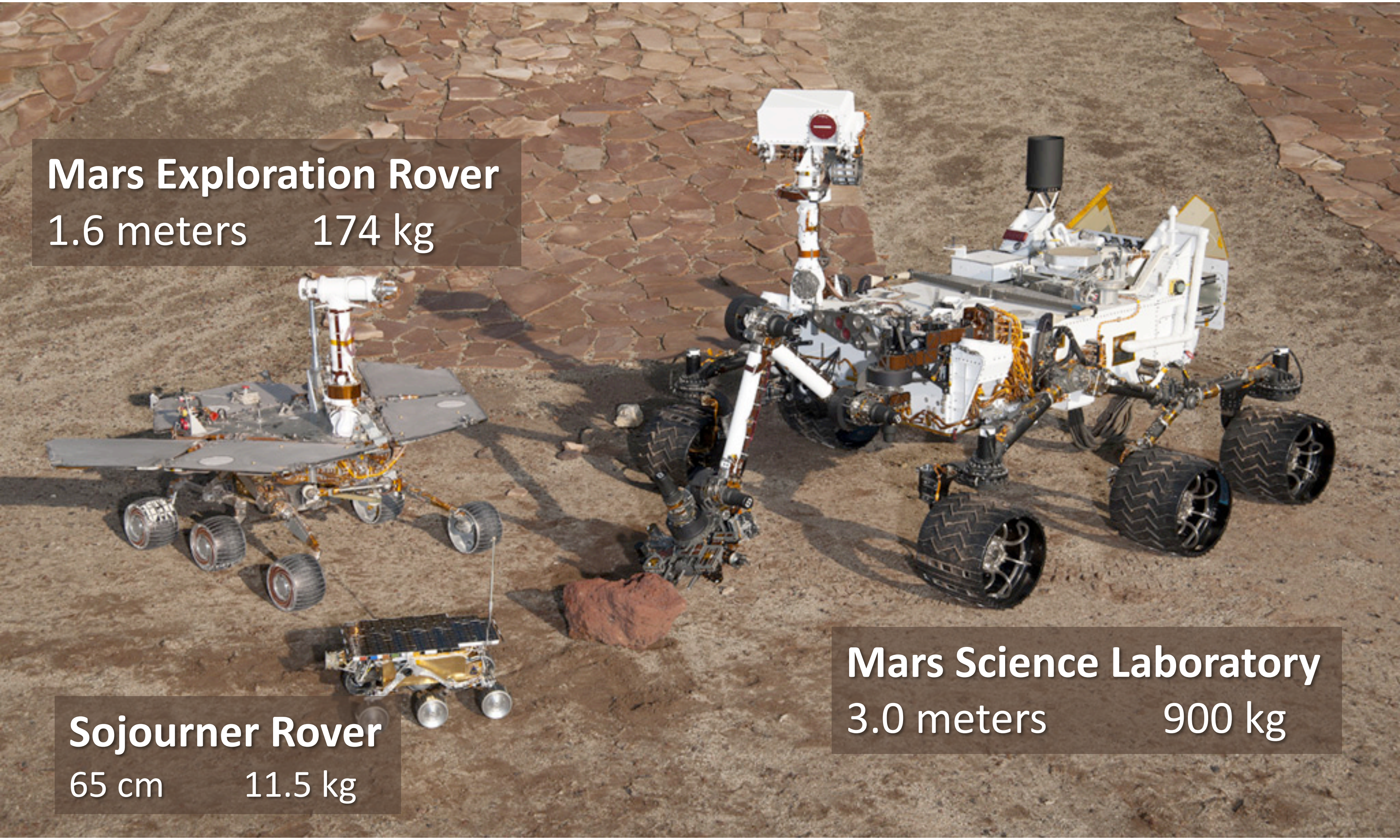


- 1st orbiter at Saturn
- 2004 – Cassini

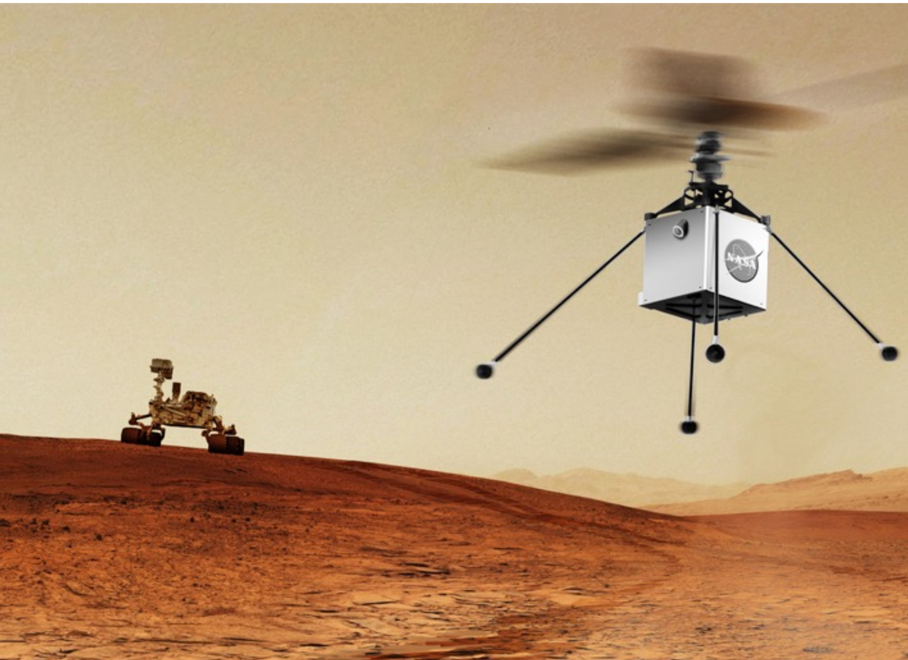


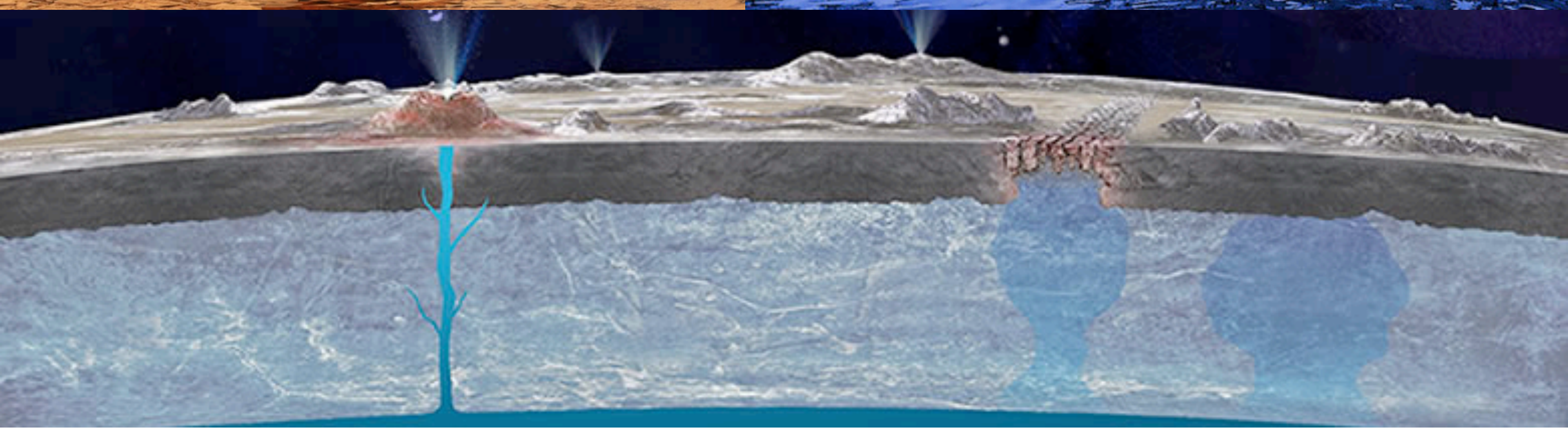
- 1st rover on Mars
- 1997 – Pathfinder

JPL Rovers


Mars Exploration Rover
1.6 meters 174 kg
Sojourner Rover
65 cm 11.5 kg
Mars Science Laboratory
3.0 meters 900 kg

JPL: What Lies Ahead

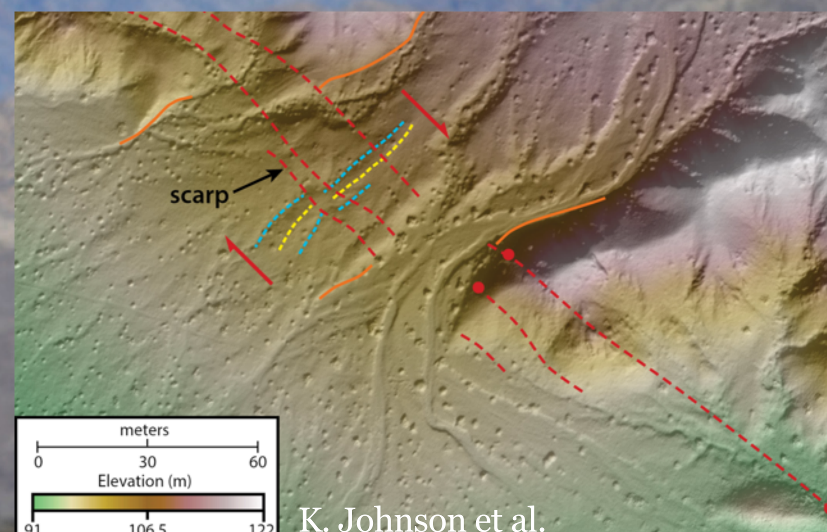




ASU/SESE

ASU Projects: Autokite

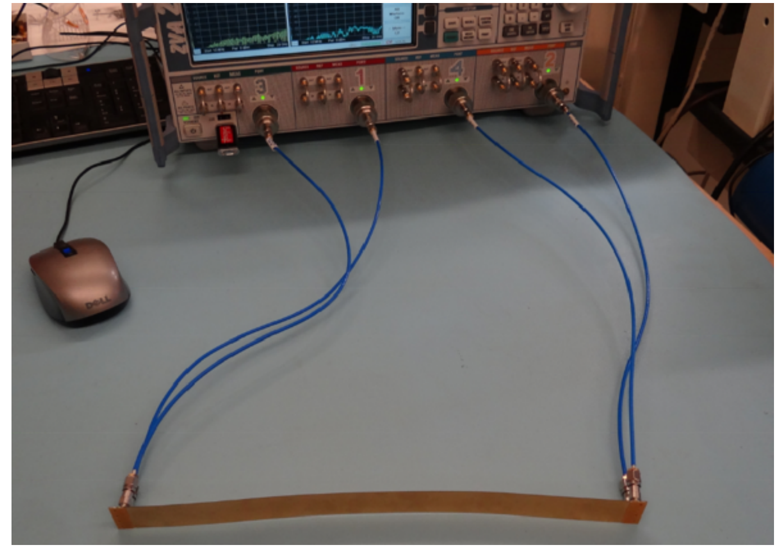
- Mapping the San Andreas Fault
- Aerial photos -> DEMs
- Low-cost, field deployable mapping solution

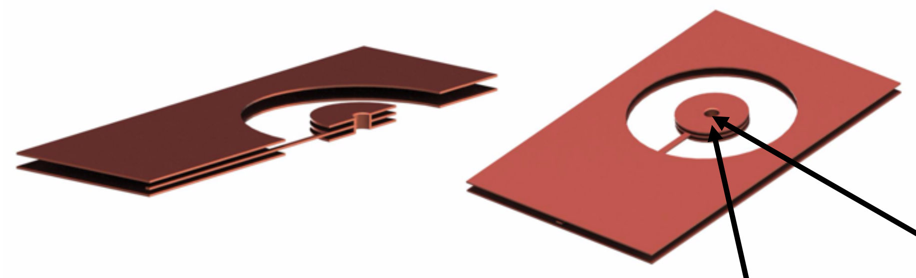


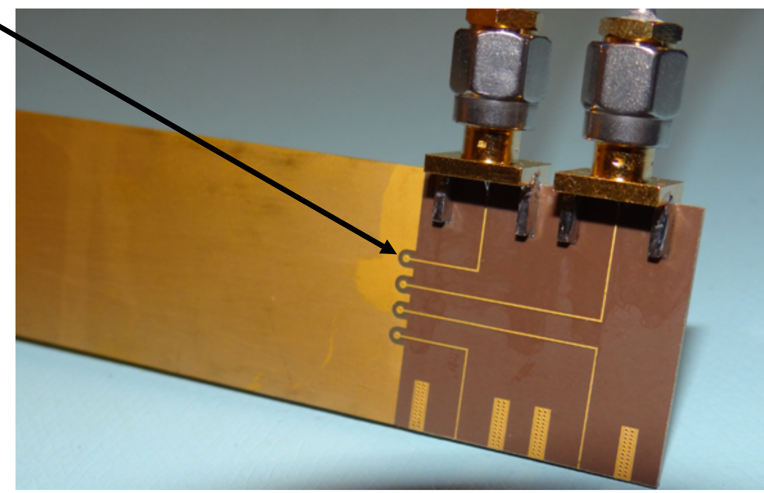
P.McGarey & S.Saripalli "Autokite experimental use of a low cost autonomous kite plane for aerial photography and reconnaissance" (2013)
K.Johnson et al. "Rapid mapping of ultrafine fault zone topography with structure from motion" (2014)

ASU Projects: Flexible Waveguide

- Cryogenic microwave signal transmission
- Channel width: ~ 0.02 mm
- Circuit thickness: ~ 0.4 mm
- Reduces connection complexity
- Allows for increases in detector resolution

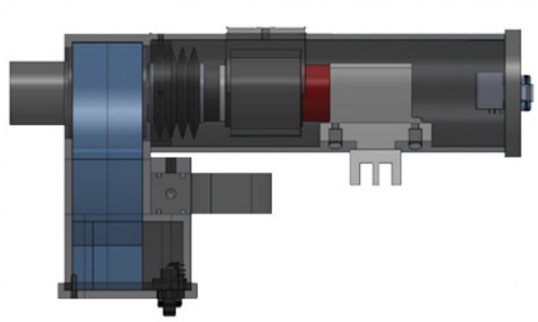




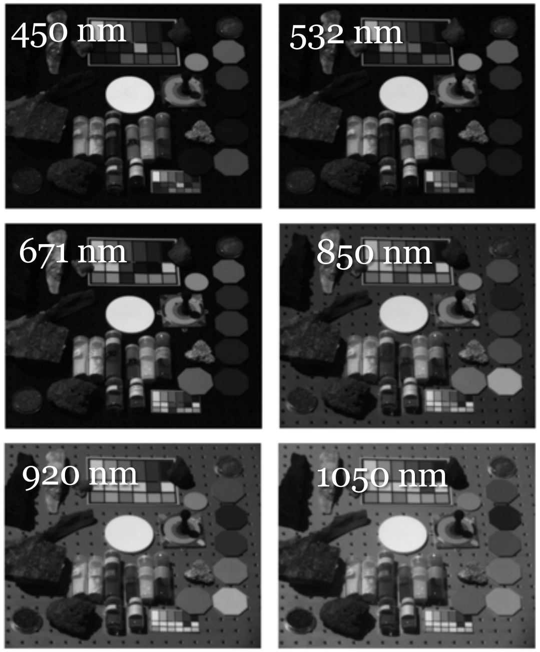


P.McGarey et al. "A 16 channel flex circuit for cryogenic microwave signal transmission" (2014)

ASU Projects: NIR-CAM



- Near Infrared Camera
- Low-Cost, 3D-printed Parts
- Inspired by *PanCam* on MERs
- Spectral Bands: 450-1050 nm



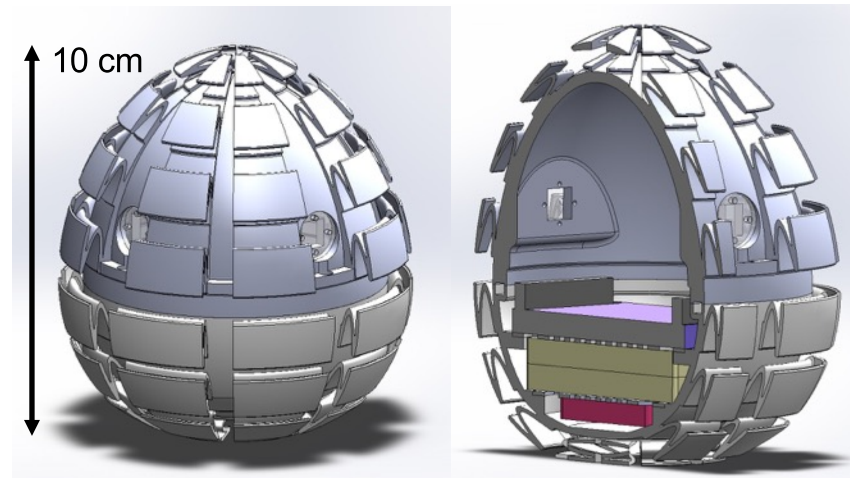
A.Krishnan et al. "NIR-CAM—Development of a Near Infrared Camera" *(*2013)

ASU Projects: HATS & EGGS

High Altitude Turbine Survey

- Student-made balloon payload
- Floated at 36 km (120k ft) for 8 hrs
- New Mexico -> Arizona
- Study wind turbine efficiency at varying altitudes.

Exploration Geology & Geophysics Sensors



- Low-cost, 3D-printed prototype
- Camera and inertial sensors
- Self-righting design
- Impact resistant

Robots for Extremely Steep Terrain

Extremely Steep Environments

Why Tethered Robots?

Electromechanical Tethers

- Support on steep terrain
- Power for long missions
- Data for communication

A Brief History of Tethered Robots

Dante
(Wettergreen et al., 1993)

JPL's TRESSA
(Huntsberger et al., 2007)

JPL's Axel & DuAxel
(Nesnas et al., 2012)

MoonRaker and Tetris
(Walker et al., 2015)

JPL's VolcanoBot
(NASA / JPL)

TReX
(McGarey et al., 2015)

TReX: Tethered Robotic eXplorer

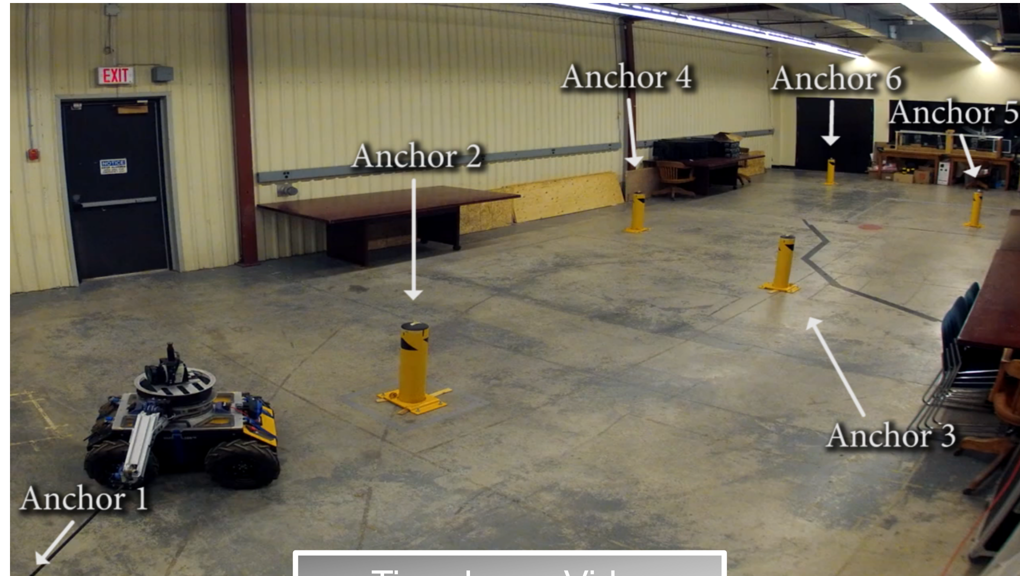
Tethered Robotic eXplorer

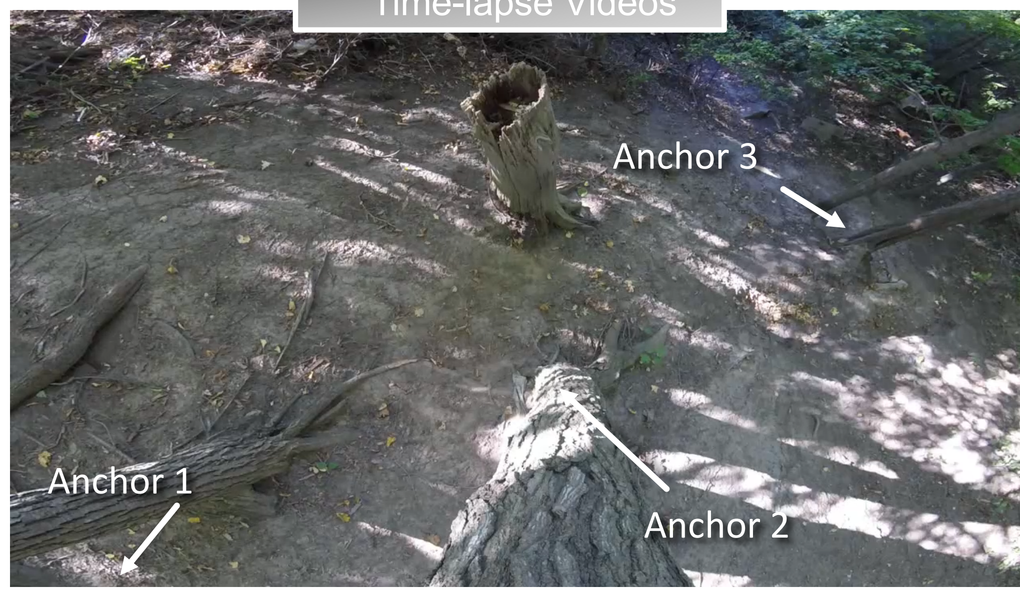
P. McGarey et al., "System Design of a Tethered Robotic Explorer (TReX) for 3D Mapping of Steep Terrain and Harsh Environments" (2016)

Tethered Autonomy

- Detect and map the sequence and location of anchors while driving
- Backtrack along the outgoing path in order to detach from anchors

P. McGarey et al., "TSLAM: Tethered Simultaneous Localixzation and Mapping for Mobile Robots" (2017)





P. McGarey et al., "The Line Leading the Blind: Towards Nonvisual Localization and Mapping for Tethered Mobile Robots" (2016)

Tethered Robotic eXplorer

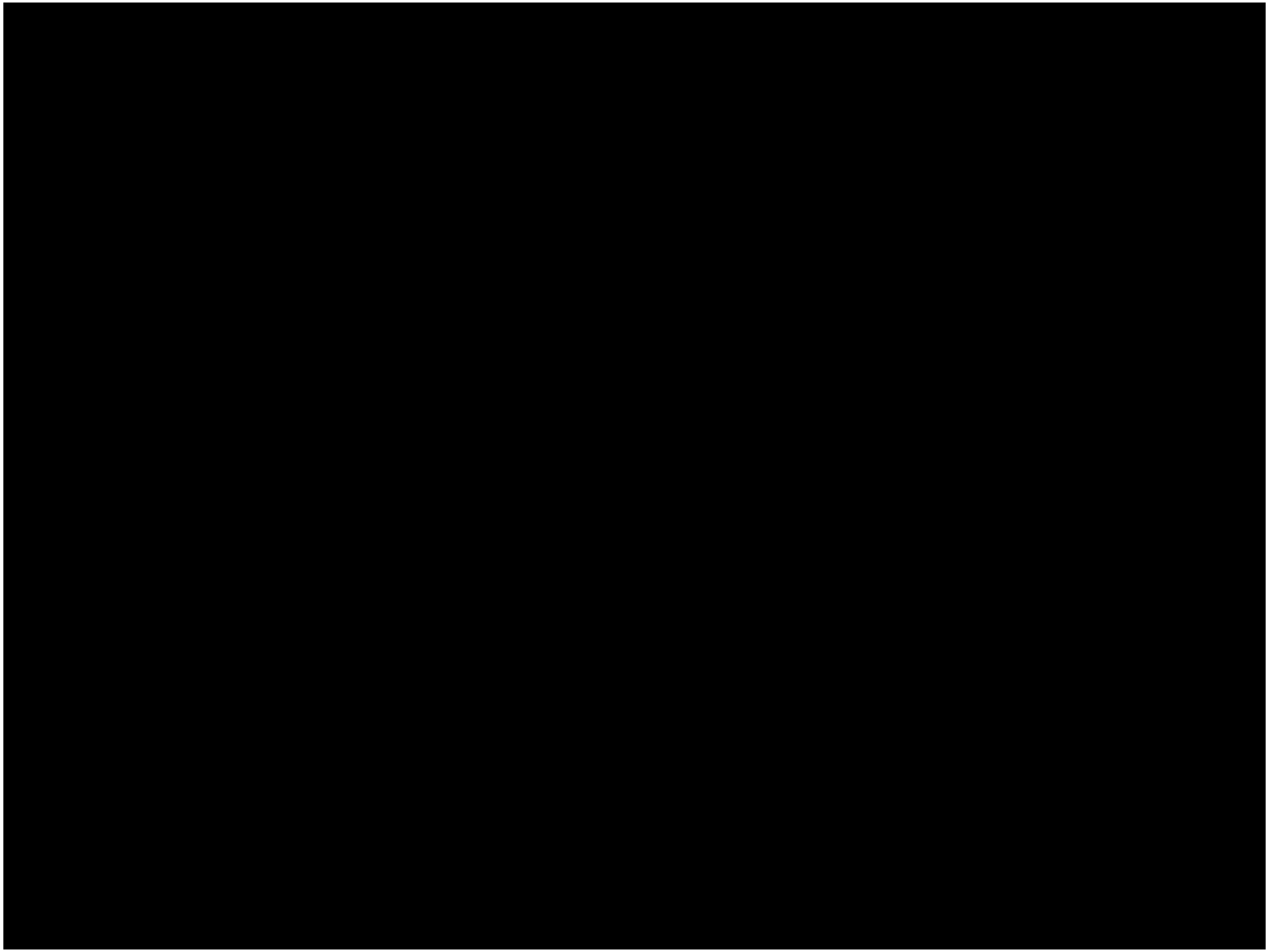
P. McGarey et al., "Field Deployment of the Tethered Robotic eXplorer to Map Extremely Steep Terrain" (2018)

Tethered Robotic eXplorer

P. McGarey et al., "Field Deployment of the Tethered Robotic eXplorer to Map Extremely Steep Terrain" (2018)

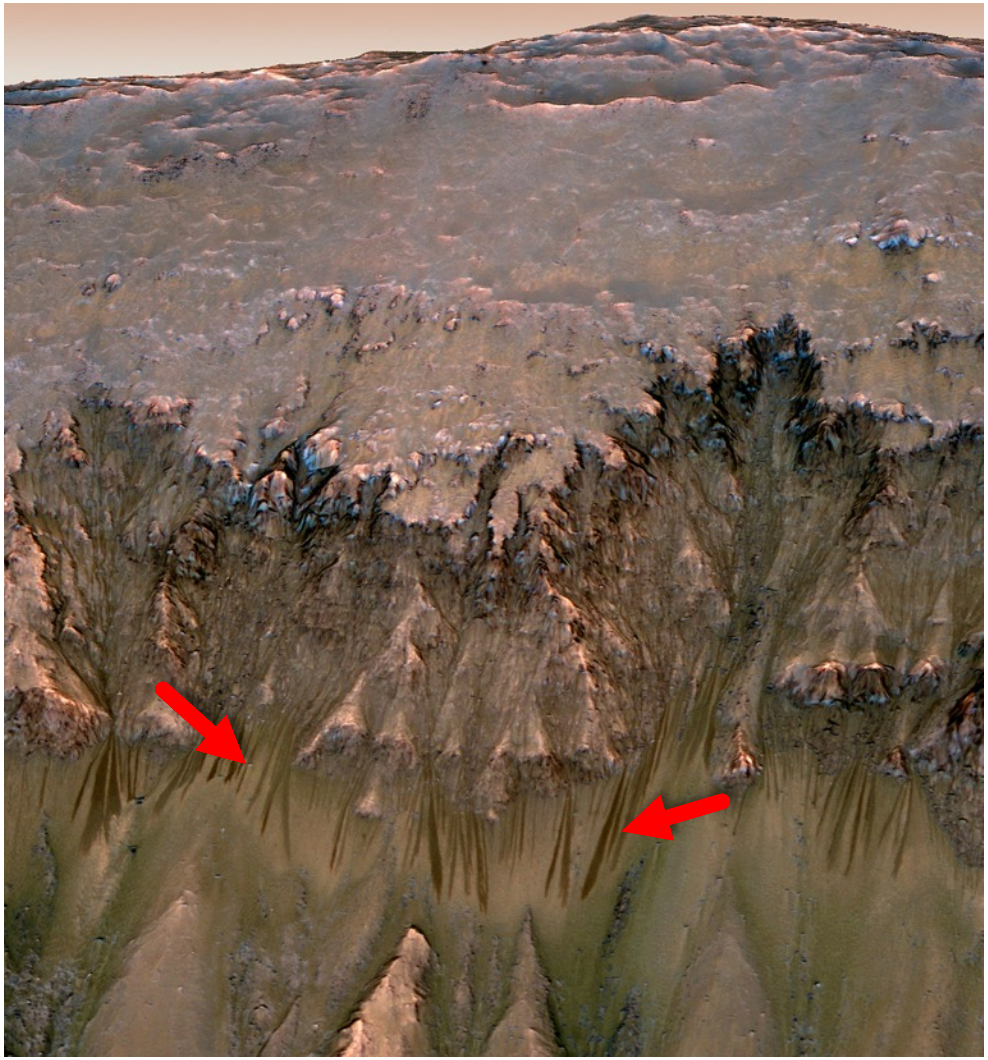
Axel/DuAxel

Axel

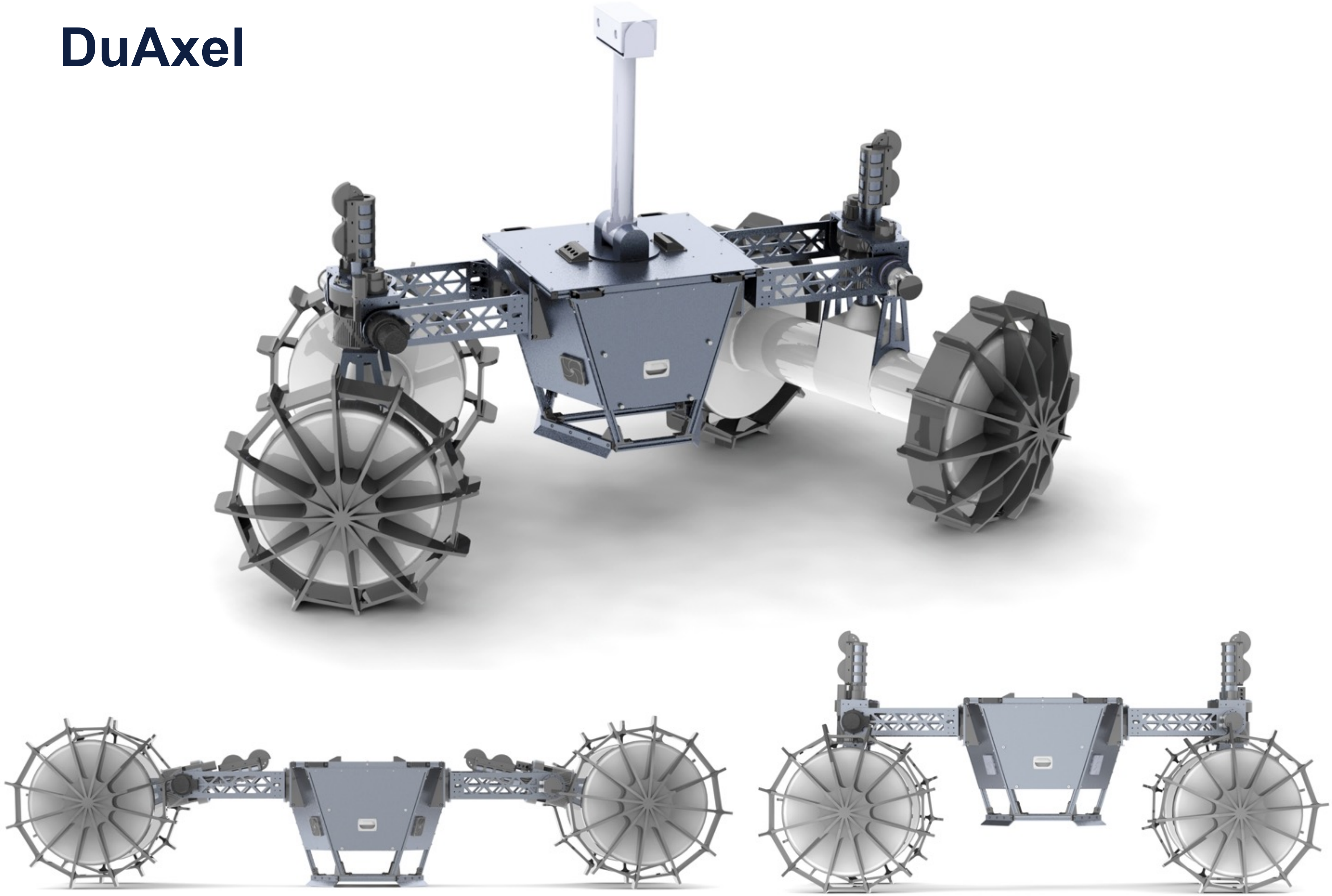


J. Matthews and I.Nesnas, "On the design of the Axel and DuAxel rovers for extreme terrain exploration" (2012)

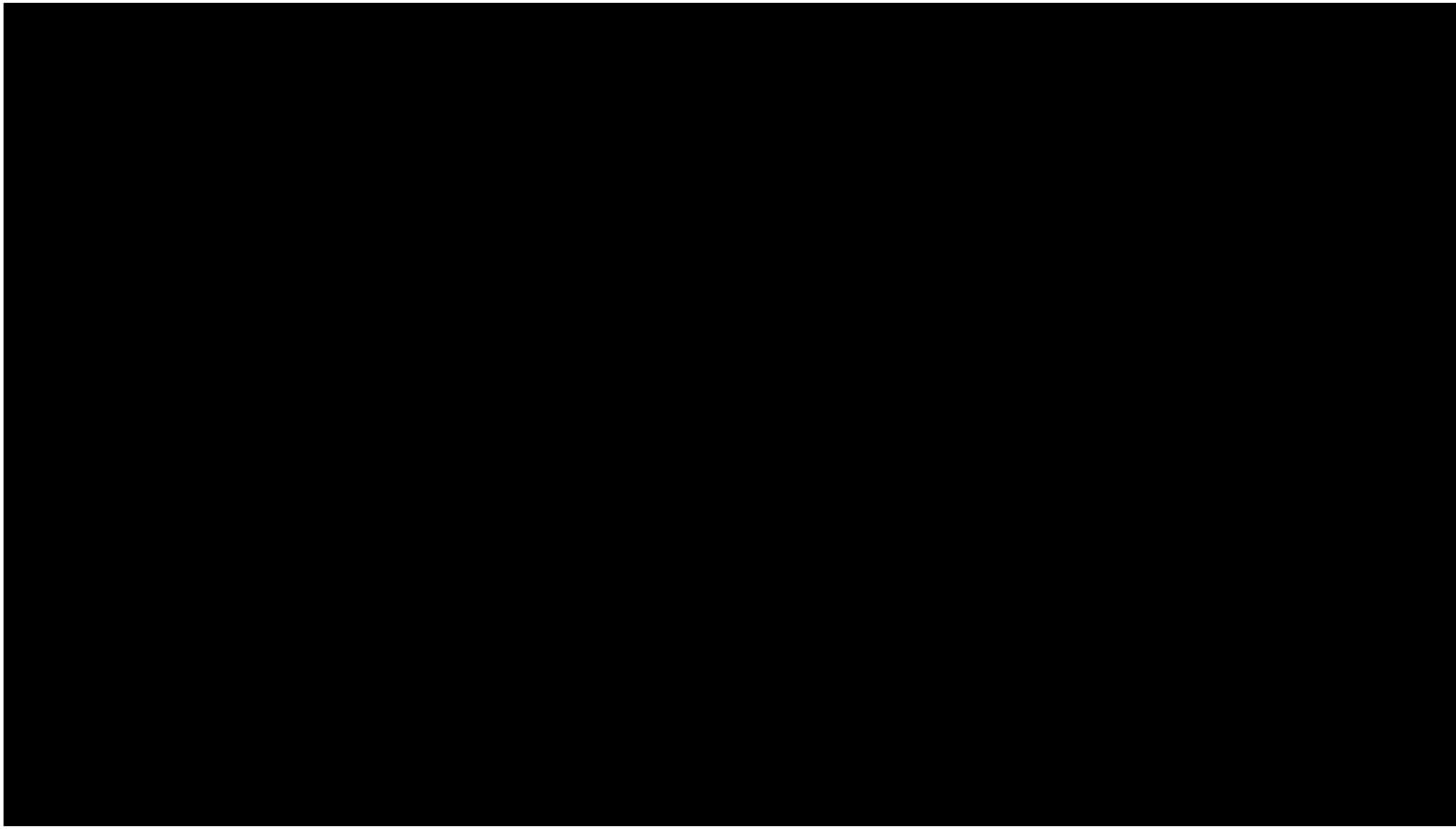
Mars: RSL Exploration



DuAxel



DuAxel



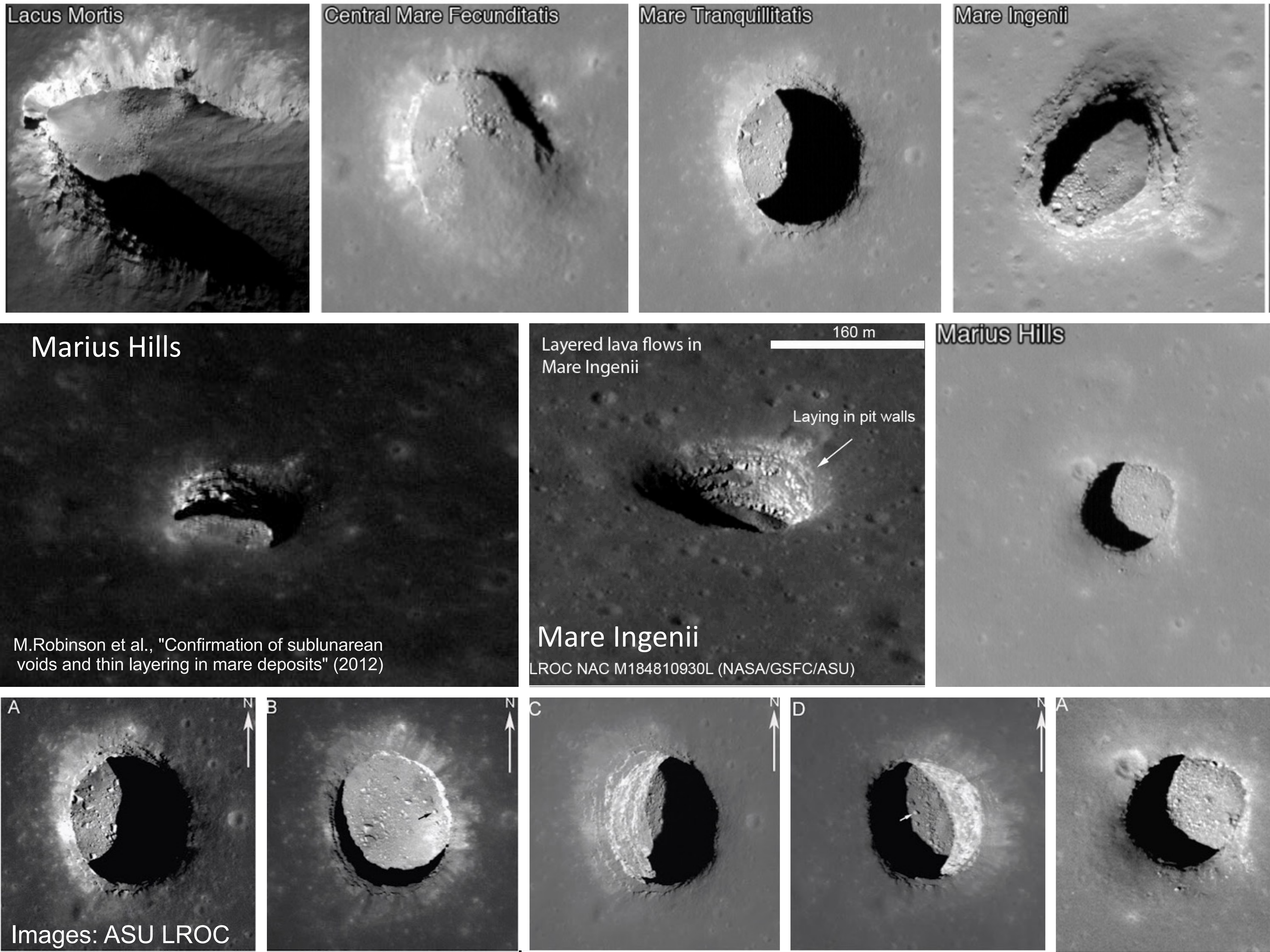
P.McGarey et al., "Towards Articulated Mobility and Efficient Docking for the DuAxel Tethered Robot System " (*To Appear, IEEE Aerospace*, 2019)

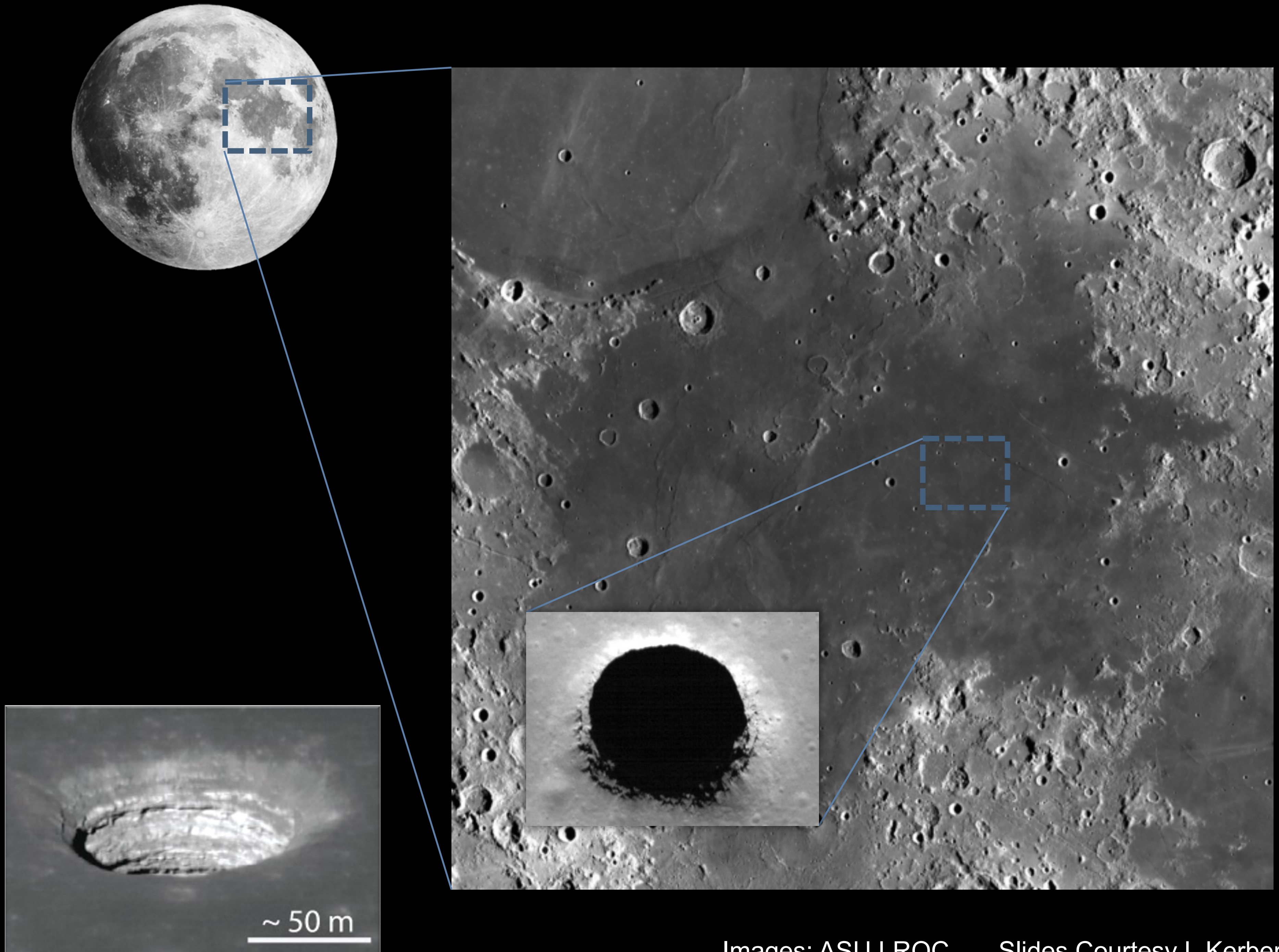
DuAxel

L.Kerber et al., "Moon Diver: A Mission Concept for Exploring the History of Lunar Mare Deposits with the Axel Extreme Terrain Rover" (2016)

MOON DIVER

Slides Courtesy L.Kerber


Lacus Mortis
Central Mare Fecunditatis
Mare Tranquillitatis
Mare Ingenii
Marius Hills
M.Robinson et al., "Confirmation of sublunarean voids and thin layering in mare deposits" (2012)
160 m
Layered lava flows in Mare Ingenii
Laying in pit walls
Mare Ingenii
LROC NAC M184810930L (NASA/GSFC/ASU)
Marius Hills
A
N
B
N
C
N
D
N
A
Images: ASU LROC

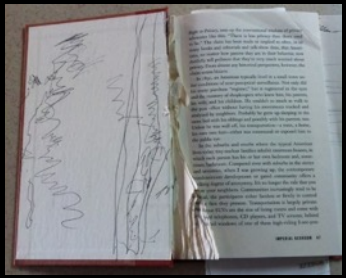


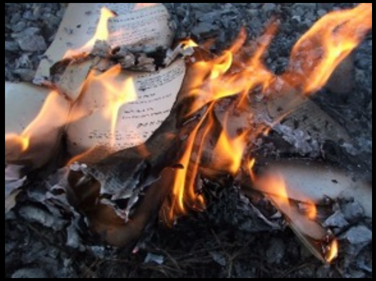
Images: ASU LROC Slides Courtesy L.Kerber

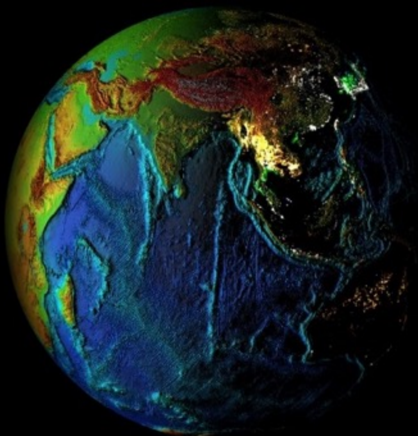
- No plate tectonics
- No weathering by wind or water
- Geologically simple

Slides Courtesy L.Kerber

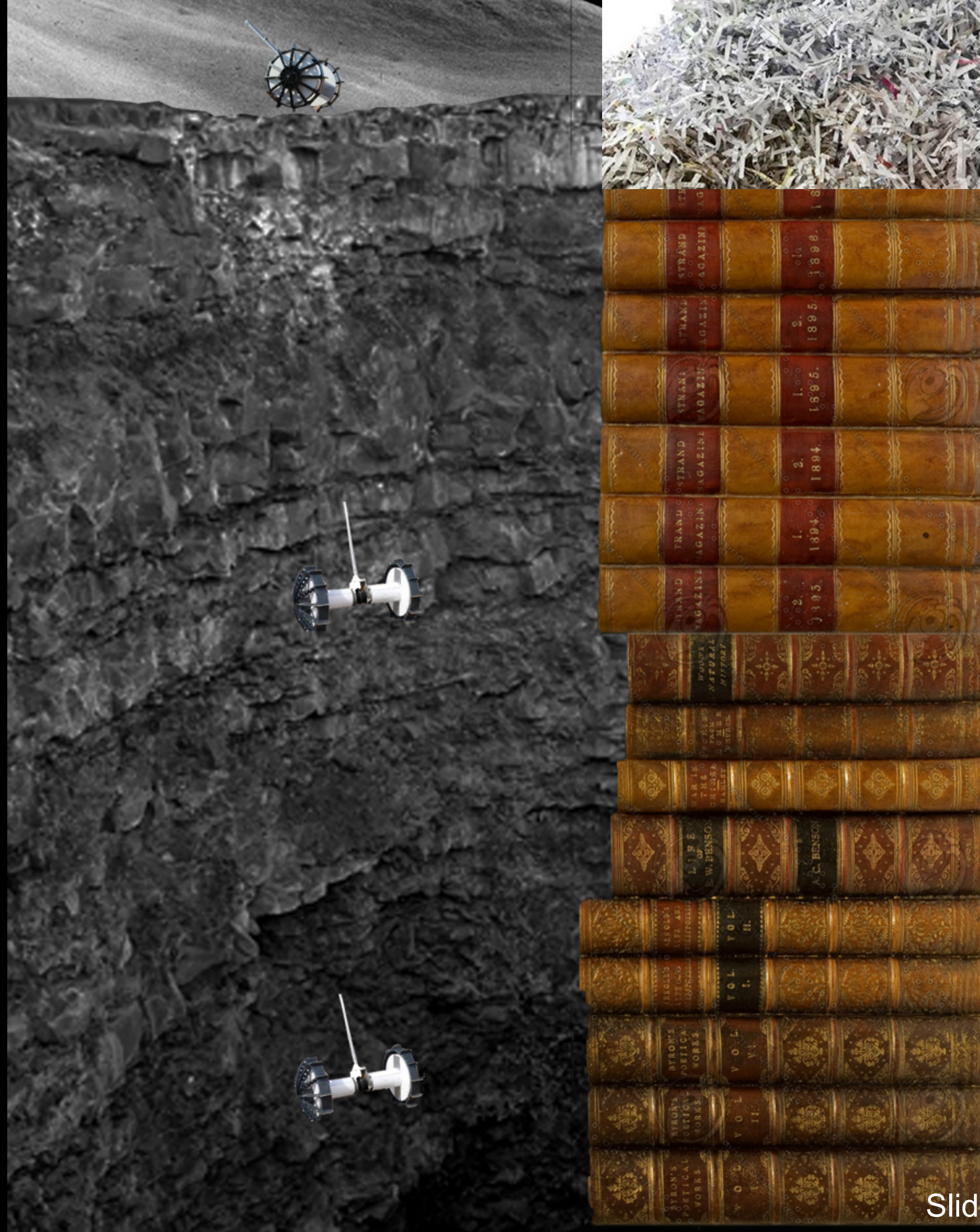
Why haven't we done this already?







Slides Courtesy L.Kerber



Slides Courtesy L.Kerber

Science Objectives

1. To understand how flood basalts are emplaced, whether it is from turbulent, extremely low viscosity flows, or complex flow fields and inflated flows

2. To understand where the mare basalts came from; plumbing the chemistry, depth, and size of the source of the magma; examining the vigor and evolution of one or more eruptions.

3. To determine how the regolith formation process transforms the basalts as they were formed on the Moon to the regolith-covered surface that is the source of both our returned sample collection and our remote sensing data suite.

Slides Courtesy L.Kerber

INSTRUMENTS

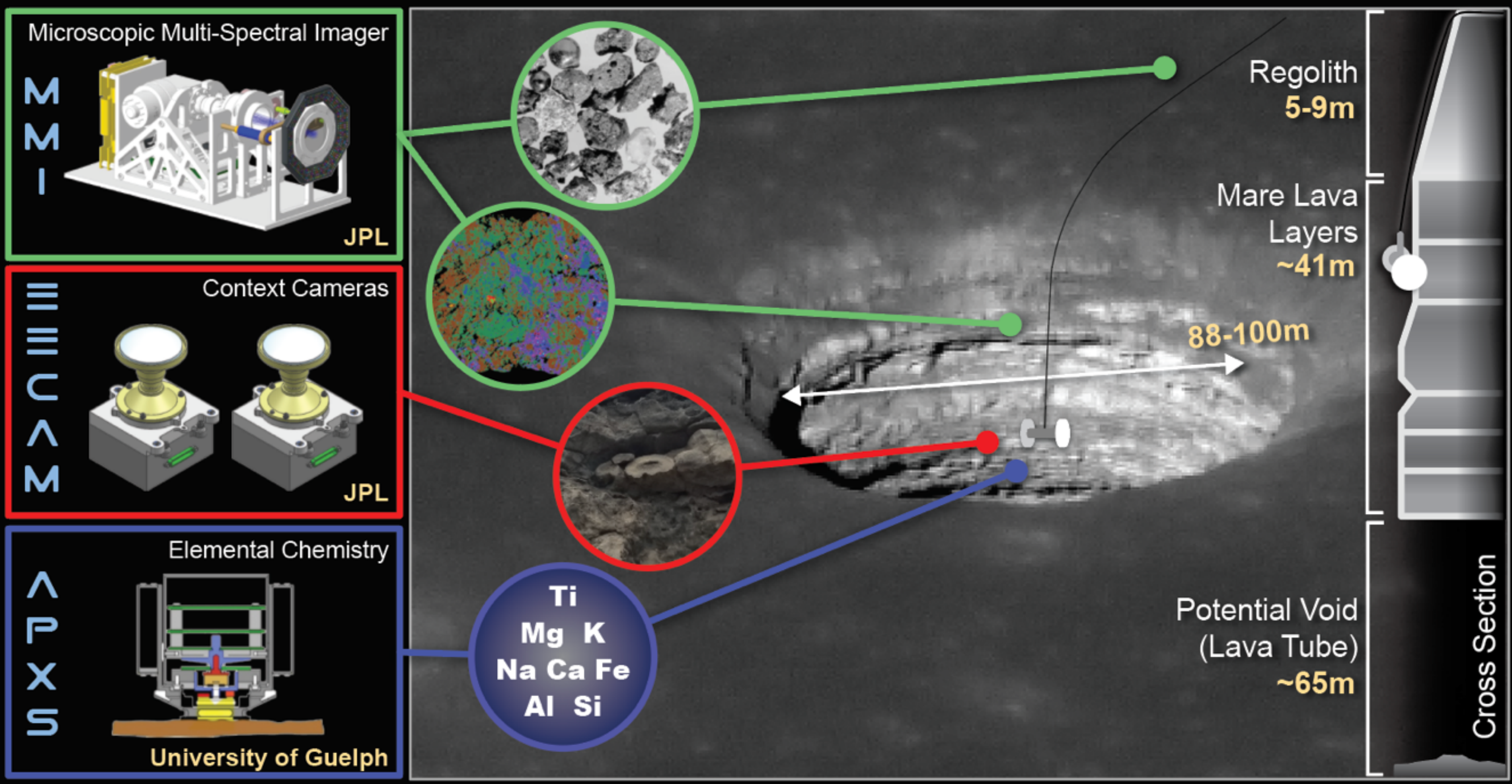
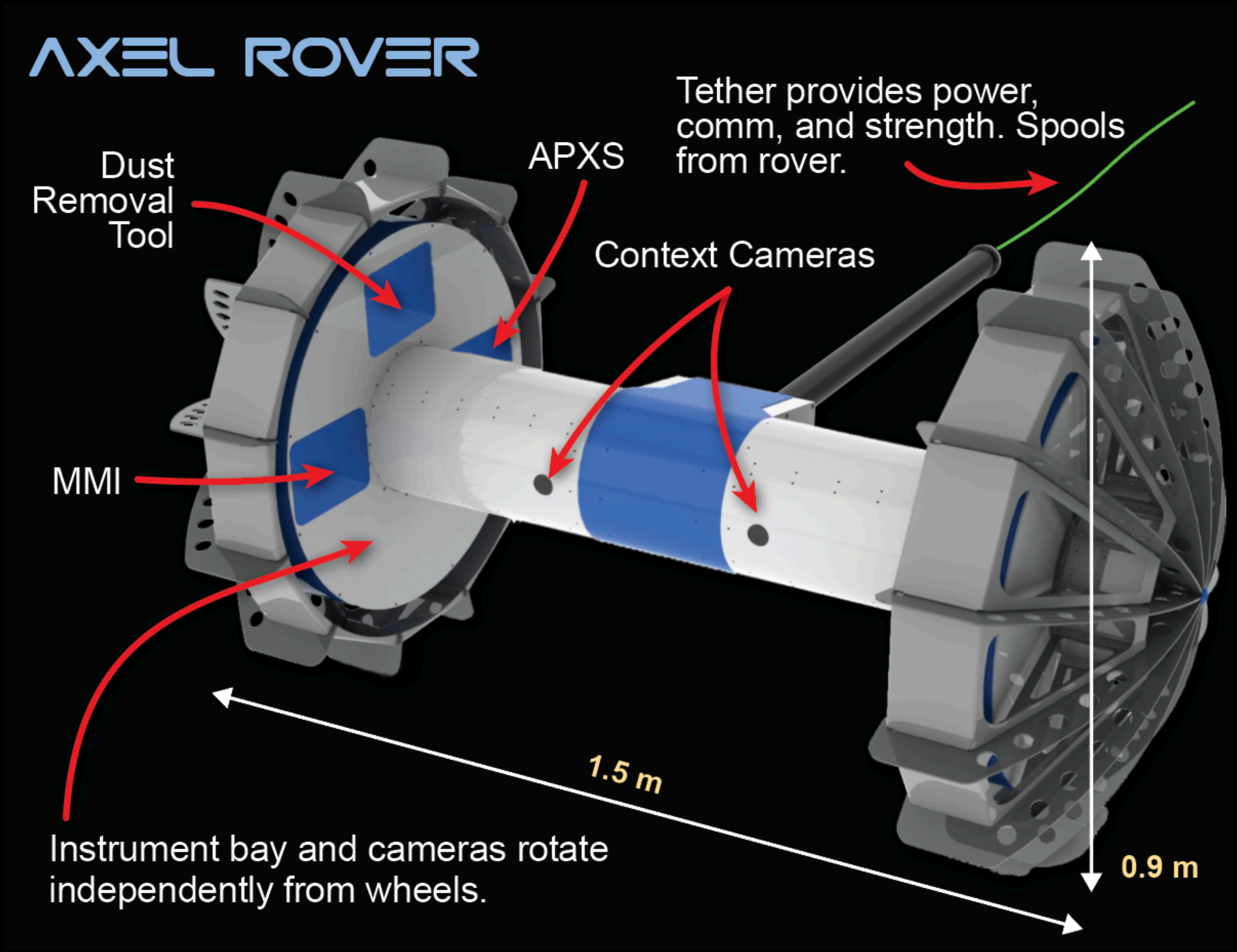
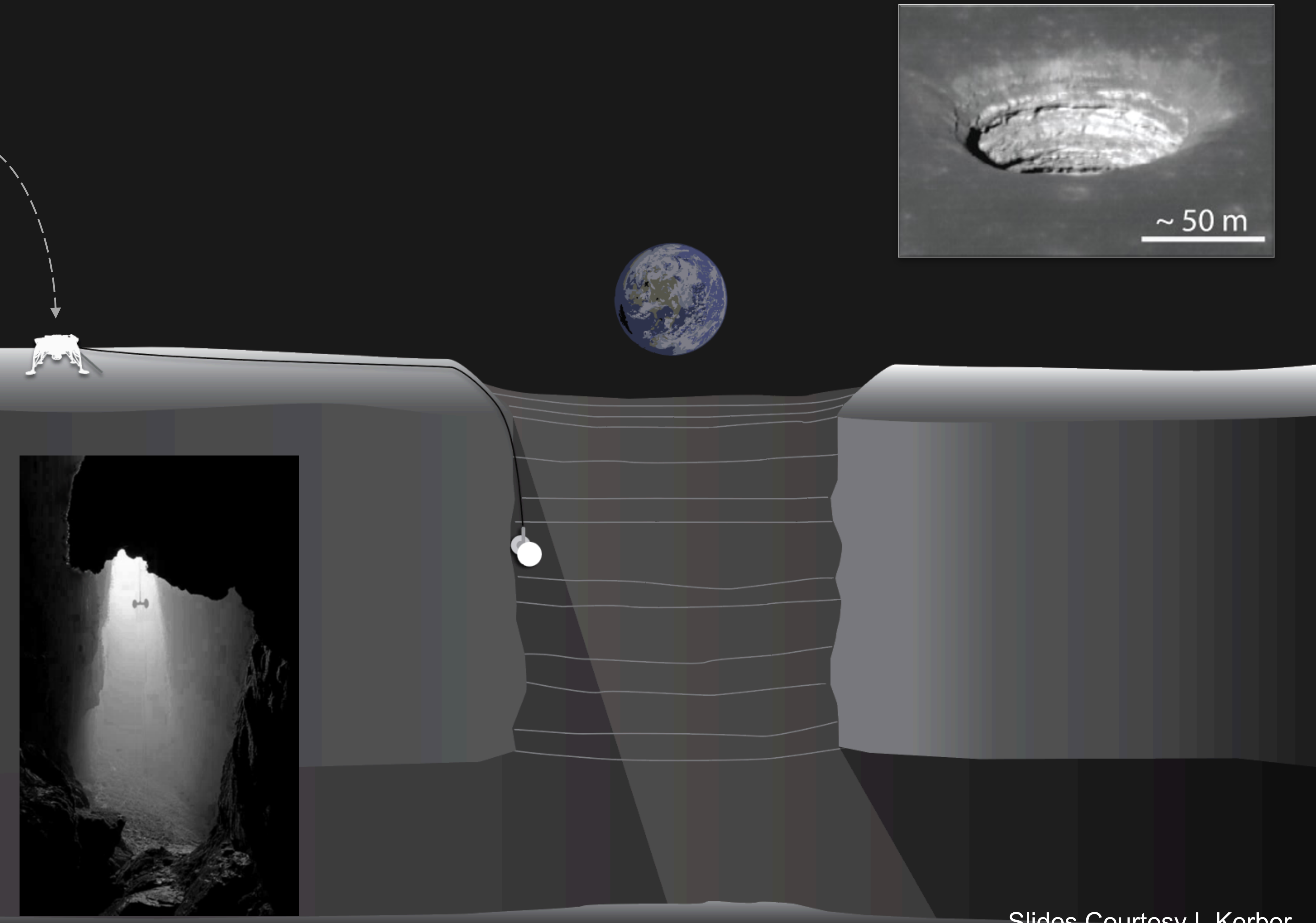


Image: ASU LROC Slides Courtesy L.Kerber

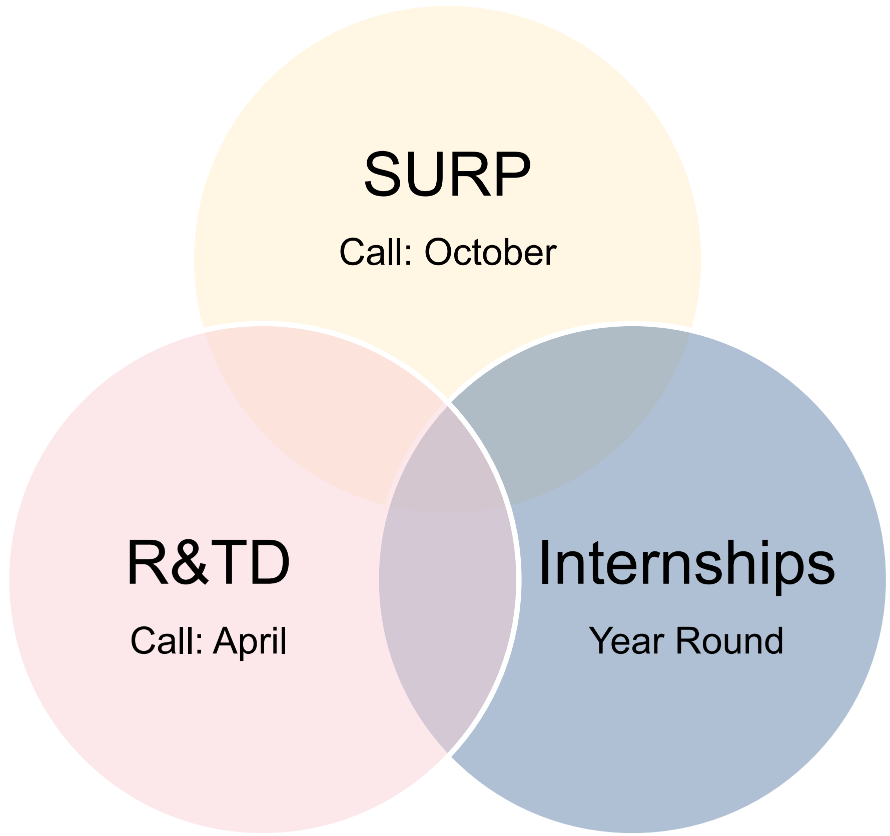


Slides Courtesy L.Kerber



Slides Courtesy L.Kerber

JPL Opportunities



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